6-15 SOIL NAIL WALLS

6-15.1 Description

This Work consists of constructing soil nail walls.

6-15.2 Materials

Materials shall meet the requirements of the following section:

Prefabricated Drainage Mat 9-33.2(3)

Other materials required, including materials for soil nails, shall be as specified in the Special Provisions.

6-15.3 Construction Requirements

6-15.3(1) General Description

Soil nailing shall consist of excavating to the layer limits shown in the Plans, drilling holes at the specified angle into the native material, placing and grouting epoxy coated or encapsulated steel reinforcing bars (soil nails) in the drilled holes, placing prefabricated drainage material and steel reinforcement, and applying a shotcrete facing over the steel reinforcement. After completing the wall to full height, the Contractor shall construct the concrete fascia panels as shown in the Plans.

All proprietary items used in the soil nailed Structure shall be installed in accordance with the manufacturer's recommendations. In the event of a conflict between the manufacturer's recommendations and these Specifications, these Specifications shall prevail.

6-15.3(2) Contractor's Experience Requirements

The Contractor or Subcontractor performing this Work shall have completed at least 5 projects, within the last 5-years, involving construction of retaining walls using soil nails or ground anchors or shall have completed the construction of 2 or more projects totaling at least 15,000-square feet of retaining wall with a minimum total of 500 soil nails or ground anchors.

The Contractor shall assign an engineer with at least 3-years of experience in the design and construction of permanently anchored or nailed Structures to supervise the Work. The Contractor shall not use consultants or manufacturer's representatives in order to meet the requirements of this section. Drill operators and on-site supervisors shall have a minimum of 1-year experience installing permanent soil nails or ground anchors.

Contractors or Subcontractors that are specifically prequalified in Class 36 Work will be considered to have met the above experience requirements.

6-15.3(3) Submittals

Work shall not begin on any soil nail wall system until the Engineer has approved all of the required submittals. The Contractor shall submit the following information in accordance with Section 6-01.9 not less than 30-calendar days prior to the start of wall excavation.

1. A brief description of each project satisfying the Contractors Experience Requirements with the Owner's name and current phone number (this item is not required if the Contractor or Subcontractor is prequalified in Class 36).
2. A list identifying the following personnel assigned to this project and their experience with permanently anchored or nailed Structures:

a. Supervising Engineer
b. Drill Operators
c. On-site Supervisors who will be assigned to the project.

3. The proposed detailed construction procedure that includes:
   a. Proposed method(s) of excavation of the soil and/or rock.
   b. A plan for the removal and control of groundwater encountered during excavation, drilling, and other earth moving activities. Include a list of the equipment used to remove and control groundwater.
   c Proposed drilling methods and equipment.
   d. Proposed hole diameter(s).
   e. Proposed method of soil nail installation.
   f. Grout mix design and procedures for placing the grout.
   g. Shotcrete mix design with compressive strength test results.
   h. Procedures for placing the shotcrete (include placement in conditions when ground water is encountered).
   i. Encapsulation system for additional corrosion protection selected for the soil nails and anchorages requiring encapsulation.
4. Detailed Working Drawings of the method proposed for the soil nail testing that includes:
   a. All necessary drawings and details to clearly describe the proposed system of jacking support, framing, and bracing to be used during testing.
   b. Calibration data for each load cell, test jack, pressure gauge, stroke counter on the grout pump, and master gauge to be used. The calibration tests shall have been performed by an independent testing Laboratory, and tests shall have been performed within 60-calendar days of the date submitted. Testing or Work shall not commence until the Engineer has approved the load cell, jack, pressure gage, and master pressure gauge calibrations.
5. Certified mill test results and typical stress-strain curves along with samples from each heat, properly marked, for the soil nail steel. The typical stress-strain curve shall be obtained by approved standard practices. The guaranteed ultimate strength, yield strength, elongation, and composition shall be specified.

6-15.3(4) Preconstruction Conference

A soil nail preconstruction conference shall be held at least 5-working days prior to the Contractor beginning any permanent soil nail Work at the site to discuss construction procedures, personnel and equipment to be used. The list of materials specified on the Record of Materials Form (ROM) for this item of Work will also be discussed. Those attending shall include:

1. (representing the Contractor) The superintendent, on site supervisors, and all foremen in charge of excavating the soil face, drilling the soil nail hole, placing the soil nail and grout, placing the shotcrete facing, and tensioning and testing the soil nail.
2. (representing the Contracting Agency) The Project Engineer, key inspection personnel, and representatives from the WSDOT Construction Office and Materials Laboratory Geotechnical Services Branch.

If the Contractor's key personnel change, or if the Contractor proposes a significant revision of the approved permanent soil nail installation plan, an additional conference shall be held before any additional permanent soil nail operations are performed.

6-15.3(5) Earthwork

The ground contour above the wall shall be established to its final configuration and slope as shown in the Plans prior to beginning excavation of the soil for the first row of soil nails. All excavation shall conform to Section 2-03.

The excavation shall proceed from the top down in a horizontal lift sequence with the ground level excavated no more than 3-feet below the elevation of the row of nails to be installed in that lift. The excavated vertical wall face should not be left unshored more than 24-hours for any reason. A lift shall not be excavated until the nail installation and reinforced shotcrete placement for the preceding lift has been completed and accepted. After a lift is excavated, the cut surface shall be cleaned of all loose materials, mud, rebound, and other foreign matter that could prevent or reduce shotcrete bond

The accuracy of the ground cut shall be such that the required thickness of shotcrete can be placed within a tolerance of plus or minus 2-inches from the defined face of the wall, and over excavation does not damage overlying shotcrete sections by undermining or other causes.

The Contractor should review the geotechnical recommendations report prepared for this project for further information on the soil conditions at the location of each wall. Copies of the geotechnical recommendations report are available for review by prospective Bidders at the location identified in the Special Provisions.

6-15.3(6) Soil Nailing

The Contractor shall not handle and transport the encapsulated soil nails until the encapsulation grout has reached sufficient strength to resist damage during handling. The Contractor shall handle the encapsulated soil nails in such a manner to prevent large deflections or distortions during handling. When handling or transporting encapsulated soil nails, the Contractor shall provide slings or other equipment necessary to prevent damage to the soil nails and the corrosion protection. The Engineer may reject any encapsulated nail which is damaged during transportation or handling. Damaged or defective encapsulation shall be repaired in accordance with the manufacturer's recommendations and as approved by the Engineer.

Soil nails shall be handled and sorted in such a manner as to avoid damage or corrosion. Prior to inserting a soil nail in the drilled hole, the Contractor and the Engineer will examine the soil nail for damage. If, in the opinion of the Engineer, the epoxy coating or bar has been damaged, the nail shall be repaired. If, in the opinion of the Engineer, the damage is beyond repair, the soil nail shall be rejected.

If, in the opinion of the Engineer, the epoxy coating can be repaired, the Contractor shall patch the coating with an Engineer approved patching material.

Nail holes shall be drilled at the locations shown in the Plans or as staked by the Engineer. The nails shall be positioned plus or minus 6-inches from the theoretical location shown in the Plans. The Contractor shall select the drilling method and the grouting pressure used for the installation of the soil nail. The drill hole shall be located so that the longitudinal axis of the drill hole and the longitudinal axis of the nail are parallel. At the point of entry the soil nail shall be installed within plus or minus 3-degrees of the inclination from horizontal shown in the Plans, and the nail shall be within plus or minus 3-degrees of a line drawn perpendicular to the face of the wall unless otherwise shown in the Plans.

Water or other liquids shall not be used to flush cuttings during drilling, but air may be used. After drilling, the nail shall be installed and fully grouted before placing the shotcrete facing. The nail shall be inserted into the drilled hole with centralizers to the desired depth in such a manner as to prevent damage to the drilled hole, sheathing or epoxy during installation. The centralizers shall provide a minimum of 0.5-inches of grout cover over the soil nail and shall be spaced no further than 8-feet apart. When the soil nail cannot be completely inserted into the drilled hole without difficulty, the Contractor shall remove the nail from the drilled hole and clean or redrill the hole to permit insertion. Partially inserted soil nails shall not be driven or forced into the hole. Subsidence, or any other detrimental impact from drilling shall be cause for immediate cessation of drilling and repair of all damages in a manner approved by the Engineer at no additional cost to the Contracting Agency.

If caving conditions are encountered, no further drilling will be allowed until the Contractor selects a method to prevent ground movement. The Contractor may use temporary casing. The Contractor's method to prevent ground movement shall be approved by the Engineer. The casings for the nail holes, if used, shall be removed as the grout is being placed.

Where necessary for stability of the excavation face, a sealing layer of shotcrete may be placed before drilling is started, or the Contractor shall have the option of drilling and grouting of nails through a stabilizing berm of native soil at the face of the excavation. The stabilizing berm shall extend horizontally from the soil face and from the face of the shotcrete a minimum distance of 1-foot, and shall be cut down from that point at a safe slope, no steeper than 1H:1V unless approved by the Engineer. The berm shall be excavated to final grade after installation and full length grouting of the nails. Nails damaged during berm excavation shall be repaired or replaced by the Contractor, to the satisfaction of the Engineer, at no added cost to the Contracting Agency.

If sections of the wall are constructed at different times than the adjacent soil nail sections, the Contractor shall use stabilizing berms, temporary slopes, or other measures, as approved by the Engineer, to prevent sloughing or failure of the adjacent soil nail sections.

If cobbles and boulders are encountered at the soil face during excavation, the Contractor shall remove all cobbles and boulders that protrude from the soil face into the design wall section and fill the void with shotcrete. All shotcrete used to fill voids created by removal of cobbles and boulders shall be incidental to shotcrete facing.

The grout equipment shall produce a grout free of lumps and undispersed cement. A positive displacement grout pump shall be used. The pump shall be equipped with a pressure gauge near the discharge end to monitor grout pressures. The pressure gauge shall be capable of measuring pressures of at least 150-psi or twice the actual grout pressures used by the Contractor, whichever is greater. The grouting equipment shall be sized to enable the grout to be pumped in 1 continuous operation. The mixer shall be capable of continuously agitating the grout.

The grout shall be injected from the lowest point of the drilled hole. The grout shall be pumped through grout tubes after insertion of the soil nail. The quantity of the grout and the grout pressures shall be recorded. The grout pressures and grout takes shall be controlled to prevent excessive ground heave.

6-15.3(7) Shotcrete Facing

Prior to placing any shotcrete on an excavated layer, the Contractor shall vertically center prefabricated drainage mat between the columns of nails as shown in the Plans. The prefabricated drainage mat shall be installed in accordance with the manufacturer's recommendations. The permeable drain side shall be placed against the exposed soil face. The prefabricated drainage mat shall be installed after each excavation lift and shall be hydraulically connected with the prefabricated drainage mat previously placed, such that the vertical flow of water is not impeded. The Contractor shall tape all joints in the prefabricated drainage mat to prevent shotcrete intrusion during shotcrete application.

The Contractor shall place steel reinforcing bars and welded wire fabric, and apply the shotcrete facing in accordance with Section 6-18 and the details shown in the Plans.

The shotcrete shall be constructed to the minimum thickness as shown in the Plans. Costs associated with additional thickness of shotcrete due to over excavation or irregularities in the cut face shall be borne by the Contractor.

Each soil nail shall be secured at the shotcrete facing with a steel plate as shown in the Plans. The plate shall be seated on a wet grout pad of a pasty consistency similar to that of mortar for brick-laying. The nut shall then be sufficiently tightened to achieve full bearing surface behind the plate. After the shotcrete and grout have had time to gain the specified strength, the nut shall be tightened with at least 100-foot-pounds of torque.

6-15.3(8) Soil Nail Testing and Acceptance

Both verification and proof testing of the nails is required. The Contractor shall supply all materials, equipment, and labor to perform the tests. The Contractor shall submit all test data to the Engineer.

The testing equipment shall include a dial gauge or vernier scale capable of measuring to 0.001-inch of the ground anchor movement. A hydraulic jack and pump shall be used to apply the test load. The movement-measuring device shall have a minimum travel equal to the theoretical elastic elongation of the total nail length plus 1-inch. The dial gauge or vernier scale shall be aligned so that its axis is within 5-degrees from the axis of the nail and shall be monitored with a reference system that is independent of the jacking system and excavation face.

The jack and pressure gauge shall be calibrated by an independent testing Laboratory as a unit. Each load cell, test jack and pressure gauge, grout pump stroke counter, and master gauge, shall be calibrated as specified in Section 6-15.3(3) item 4b. Additionally, the Contractor shall not use load cells, test jacks and pressure gauges, grout pump stroke counters, and master gauges, greater than 60-calendar days past their most recent calibration date, until such items are re-calibrated by an independent testing Laboratory.

The pressure gauge shall be graduated in increments of either 100-psi or 2-percent of the maximum test load, whichever is less. The pressure gauge shall be selected to place the maximum test load within the middle ⅔ of the range of the gauge. The ram travel of the jack shall not be less than the theoretical elastic elongation of the total length at the maximum test load plus 1-inch. The jack shall be independently supported and centered over the nail so that the nail does not carry the weight of the jack. The Contractor shall have a second calibrated jack pressure gauge at the site. Calibration data shall provide a specific reference to the jack and the pressure gauge.

The loads on the nails during the verification and proof tests shall be monitored to verify consistency of load – defined as maintaining the test load within 5-percent of the specified value. Verification and proof test loads less than 20,000-pounds or sustained for 5-minutes or less shall be monitored by the jack pressure gauge alone. Verification and proof test loads equal to or greater than 20,000-pounds and sustained for longer than 5-minutes shall be monitored with the assistance of an electric or hydraulic load cell. The Contractor shall provide the load cell, the readout device, and a recent calibration curve. The load cell shall be selected to place the maximum test load within the middle 2/3 of the range of the load cell. The load cell shall be mounted between the jack and the anchor plate. The stressing equipment shall be placed over the nail in such a manner that the jack bearing plates, load cell and stressing anchorage are in alignment.

Nails to be tested shall be initially grouted no closer to the excavation face than the dimension shown in the Plans. After placing the grout, the nail shall remain undisturbed until the grout has reached a strength sufficient to provide resistance during testing. Grouting to the excavation face shall be completed after successful testing has been performed. Test nails that are not part of the permanent wall may be left in the ground provided the drill holes for the nails are completely filled with grout or non-structural filler after testing.

Load testing shall be performed against a temporary bearing yoke or reaction frame that bears directly against the existing soil or the shotcrete facing. Temporary bearing pads shall be kept a minimum of 12-inches from the edges of the drilled hole unless a rigid steel plate is used to distribute the stress around the drilled hole. If a steel plate is used, it shall be a minimum of 3-feet square and of sufficient thickness that it will distribute the load evenly to the soil. Where the reaction frame bears directly against the shotcrete, the reaction frame shall be designed to prevent fracture of the shotcrete. No part of the reaction frame shall bear within 12-inches of the edge of the test nail blockout unless otherwise approved by the Engineer.

The soil nail load monitoring procedure for verification and proof test load greater than 20,000-pounds and sustained for longer than 5-minutes shall be as follows:

1. For each increment of load, attainment of the load shall be initially established and confirmed by the reading taken from the jack gauge.
2. Once the soil nail anchor load has been stabilized, based on the jack gauge reading, the load cell readout device shall immediately be read and recorded to establish the load cell reading to be used at this load. The load cell reading is intended only as a confirmation of a stable soil nail load, and shall not be taken as the actual load on the soil nail.
3. During the time period that the load on the soil nail is held at this load increment, the Contractor shall monitor the load cell reading. The Contractor shall adjust the jack pressure as necessary to maintain the initial load cell reading. Jack pressure adjustment for any other reason will not be allowed.
4. Soil nail elongation measurements shall be taken at each load increment as specified in Sections 6-15.3(8)A and 6-15.3(8)B.
5. Steps 1 through 4 shall be repeated at each increment of load, in accordance with the load sequence specified in Sections 6-15.3(8)A and 6-15.3(8)B.

6-15.3(8)A Verification Testing

Verification testing shall be performed on nails installed within the pattern of production nails to verify the Contractor's procedures, hole diameter, and design assumptions. No drilling or installation of production nails will be permitted in any ground/rock unit unless successful verification testing of anchors in that unit has been completed and approved by the Engineer, using the same equipment, methods, nail inclination, nail length, and hole diameter as planned for the production nails. Changes in the drilling or installation method may require additional verification testing as determined by the Engineer and shall be done at no additional expense to the Contracting Agency. Verification tests may be performed prior to excavation for the soil nail wall.

Successful verification tests are required within the limits as specified in the Special Provisions. Test nail locations within these limits shall be at locations selected by the Engineer.

The design details of the verification testing, including the system for distributing test load pressures to the excavation surface and appropriate nail bar size and reaction plate, shall be developed by the Contractor, subject to approval by the Engineer. The intent is to stress the bond between the grout and the surrounding soil/rock to at least twice the design load transfer.

The bar shall be proportioned such that the maximum stress at 200-percent of the test load does not exceed 80-percent of the yield strength of the steel. The jack shall be positioned at the beginning of the test such that unloading and repositioning of the jack during the test will not be required. The verification tests shall be made by incrementally loading the nails in accordance with the following schedule of hold time:

AL	1-minute
0.25TL	10-minutes
0.50TL	10-minutes
0.75TL	10-minutes
1.00TL	10-minutes
1.25TL	10-minutes
1.50TL	60-minutes
1.75TL	10-minutes
2.00TL	10-minutes

AL = Nail Alignment Load

TL = Nail Test Load

The test load shall be determined by the following equation = Test Load (TL) = Bond Length (BL) X Design Load Transfer (DLT).

The load shall be applied in increments of 25-percent of the test load. Each load increment shall be held for at least 10-minutes. Measurement of nail movement shall be obtained at each load increment. The load-hold period shall start as soon as the load is applied and the nail movement with respect to a fixed reference shall be measured and recorded at 1-minute, 2, 3, 5, 6, 10, 20, 30, 50, and 60-minutes.

The Engineer will evaluate the results of each verification test and make a determination of the suitability of the test and of the Contractor's proposed production nail design and installation system. Tests that fail to meet the design criteria will require additional verification testing or an approved revision to the Contractor's proposed production nail design and installation system. If a nail fails in creep, retesting will not be allowed.

A verification tested nail with a 60-minute load hold at 1.50TL is acceptable if:

1. The nail carries the test load with a creep rate that does not exceed 0.08-inch per log cycle of time and is at a linear or decreasing creep rate.
2. The total movement at the test load exceeds 80-percent of the theoretical elastic elongation of the non-bonded length.

Furthermore, a pullout failure shall not occur for the verification test anchor at the 2.0TL maximum load. Pullout failure load is defined as the load at which attempts to increase the test load result only in continued pullout movement of the test nail without a sustainable increase in the test load.

The nails used for verification tests shall be sacrificial and shall not be used for production. The Contractor shall cut and remove the exposed end of all soil nails used for verification tests a minimum of 2-feet inside the finished ground line.

6-15.3(8)B Proof Testing

Proof tests shall be performed on production nails at the locations selected by the Engineer. Up to 5-percent of the production nails will be tested. Prior to testing, only the bond length (BL) portion of the nail shall be grouted. The Contractor shall maintain the side-wall stability of the drill hole for the non-grouted portion during the test. Once proof testing is completed, the remainder of the proof tested nail shall be grouted. The bond length shall be determined from the Nail Schedule and Test Nail Detail shown in the Plans.

Proof tests shall be performed by incrementally loading the nail in accordance with the schedule below. The anchor movement shall be measured and recorded to the nearest 0.001-inch with respect to an independent fixed reference point in the same manner as for the verification tests at the alignment load and at each increment of load. The load shall be monitored in accordance with Section 6-15.3(8). The scheduling of hold times shall be as follows:

AL	1-minute
0.25TL	5-minutes
0.50TL	5-minutes
0.75TL	5-minutes
1.00TL	5-minutes
1.25TL	5-minutes
1.50TL	10-minutes

AL = Nail Alignment Load

TL = Nail Test Load

The maximum load in a proof test shall be held for 10-minutes. The load hold period shall start as soon as the maximum load is applied and the nail movement with respect to an independent fixed reference shall be measured and recorded at 1, 2, 3, 4, 5, 6, and 10-minutes. The nail movement between 1-minute and 10-minutes shall not exceed 0.04-inches. If the nail movement between 1 and 10-minutes exceeds 0.04-inches, the maximum load shall be held an additional 50-minutes. If the load hold is extended, the nail movement shall be recorded at 20, 30, 50, and 60-minutes. If a nail fails in creep, retesting will not be allowed.

A proof tested nail is acceptable if:

1. The nail carries the maximum load with less than 0.04-inches of movement between 1-minute and 10-minutes, unless the load hold extended to 60-minutes, in which case the nail would be acceptable if the creep rate does not exceed 0.08-inches per log cycle of time.
2. The total movement at the maximum load exceeded 80-percent of the theoretical elastic elongation of the non-bonded length.
3 The creep rate is not increasing with time during the load hold period.

Due to the requirement for a non-bonded zone for testing purposes, the Contractor shall develop an installation method which will assure the stability of the non-bonded portion of the hole during testing and will allow for the non bonded zone to be grouted against the ground after testing.

If a proof test fails, the Engineer may direct the Contractor to replace some or all of the installed production nails between the failed test and an adjacent proof test nail that has met the test criteria. The Engineer may also require additional proof testing. All additional proof tests, and all installation of additional or modified nails, shall be performed at no additional expense to the Contracting Agency.

6-15.3(9) Concrete Fascia Panels

The Contractor shall construct the concrete fascia panels in accordance with Section 6-02 and the details in the Plans. The concrete fascia panels shall be cured in accordance with the Section 6-02.3(11) requirements specified for retaining walls. The Contractor shall provide the specified surface finish as noted, and to the limits shown, in the Plans to the exterior concrete surface. When noted in the Plans, the Contractor shall apply pigmented sealer to the limits shown in the Plans.

Asphalt or cement concrete gutter shall be constructed as shown in the Plans and as specified in Section 8-04.

6-15.4 Measurement

Prefabricated drainage mat will be measured by the square yard of material furnished and installed.

Soil nails will be measured per each for each soil nail installed and accepted.

The soil nail verification testing program will not be measured but will be paid for on a lump sum basis.

Shotcrete facing and concrete fascia panel will be measured by the square foot surface area of the completed facing or fascia panel, measured to the neat lines of the facing or panel as shown in the Plans.

6-15.5 Payment

Payment will be made in accordance with Section 1-04.1 for each of the following Bid items when they are included in the Proposal:

"Soil Nail – Epoxy Coated", per each.

"Soil Nail – Encapsulated", per each.

All costs in connection with furnishing and installing the soil nails as specified shall be included in the unit Contract price per each for "Soil Nail - ___", including all drilling, grouting, centralizers, bearing plates, welded shear connectors, nuts, proof testing, and other Work required for installation of each soil nail.

"Prefabricated Drainage Mat", per square yard.

"Soil Nail Verification Test", lump sum.

"Concrete Fascia Panel", per square foot.

All costs in connection with constructing the concrete fascia panels as specified shall be included in the unit Contract price per square foot for "Concrete Fascia Panel", including all steel reinforcing bars, premolded joint filler, polyethylene bond breaker strip, joint sealant, PVC pipe for weep holes, exterior surface finish, and pigmented sealer (when specified).

Shotcrete facing will be paid for in accordance with Section 6-18.5.

Unless otherwise specified, all costs in connection with excavation in front of the back face of the shotcrete facing shall be included in the unit Contract price per cubic yard for "Roadway Excavation" or "Roadway Excavation Incl. Haul" as specified in Section 2-03.5.